SECTION 6

MAPPING TOOLS FOR RISK ASSESSMENT AND RISK MANAGEMENT

6.1 OVERVIEW OF POPULATION AND CONTAMINANT MAPPING

Mapping is useful for displaying geographic data concerning chemical contaminants, consumer populations, risks, locations of consumption advisories, or other related information. Mapping allows risk assessors and risk managers to work with a visual display of data that is easily understood and that may show patterns of contamination and risk useful to risk managers. A variety of methods for using mapping in risk assessment and management are discussed in this section. Although presented in the risk assessment volume in this series, this information may be useful to State staff in planning and displaying sampling and analysis activities and results, as well as for risk management and risk communication. Additional assistance with mapping may be obtained from mapping software companies, university geography departments, and EPA Regional and Headquarters offices that often use geographic information systems (GISs).

6.2 OBJECTIVES OF MAPPING

Mapping can be useful at every stage in the fish advisory development process and can be used to

- Display sampling results with respect to fish species and chemical contaminant levels
- Display population and/or fisher population density
- Display locations of recreational and subsistence fish harvests
- Spatially locate populations at high risk, based on high fish consumption rates
- Delineate areas where fish consumption advisories have been issued
- Determine where data gaps exist for purposes of targeting data collection efforts appropriately.

Information can be mapped in various combinations to address specific concerns. For example, mapping information on fisher population density and on contaminant concentrations can be combined to produce an overview of populations that may be at risk. Further discussion of mapping as a technique for risk communication is included in Volume 4 of this guidance series, *Risk Communication*. Risk managers may find particular use for maps showing locations where contamination exceeds screening levels or where a set risk level is estimated to occur (e.g., greater than 100 percent of the RfD for noncarcinogenic effects, greater than 1 in 1 million risk for carcinogens).

6.3 BASIC GIS CONCEPTS FOR POPULATION AND CONTAMINANT MAPPING

A GIS stores information about the world as a collection of thematic layers that can be linked together by geography. A GIS is commonly defined as a computer system designed to allow users to collect, manage, and analyze large volumes of spatially referenced files and associated data layers. GISs are used for solving complex research, planning, and management problems. The major components of a GIS are: a computer with software providing a special user interface designed to facilitate dealing with spatial databases (or layers); database management software that allows spatial data sets to be created and maintained, along with features for importing data from other computer systems; a set of software tools to carry out spatial data processing and analyses of the GIS layers; and a high-resolution display system (usually a graphics monitor and a high-quality printer or plotter) to create the maps that summarize the spatial analysis work.

Two technologies have been developed for taking information about features in the real world and converting these into GIS data layer. Raster technologies were developed largely in working with satellite images, high-altitude aerial photographs, or other remote sensing data where the information is organized around small squares or pixels similar to the “dots” found in the photographs printed in books or newspapers. Vector technologies involve a richer set of objects for breaking down the real world into features. Instead of small pixel patches, vector technologies can organize data using a more intuitive set of polygons (e.g., the boundary of a town), lines or arcs (e.g., rivers or roads), and points (e.g., the location of a Superfund site). Figure 6-1 illustrates the underlying differences between raster and vector approaches for organizing aspects of the real world into the digitized features contained in GIS data layers. Table 6-1 compares the advantages and disadvantages and recommends uses of raster- and vector-based GIS programs.

Although there was formerly a major divergence between GIS systems designed to handle raster as opposed to vector data layers, most GIS packages now will either contain procedures for handling both data types or provide transformation programs that can convert one format to the other. While raster-based systems have advantages when dealing with information such as land cover or soil types over large geographic areas, vector approaches have become increasingly popular for most routine GIS analysis applications.

To convert real world information into GIS data layers, important objects and features must be precisely located so that different data layers will overlay correctly. Geographic information contains either an explicit geographic reference

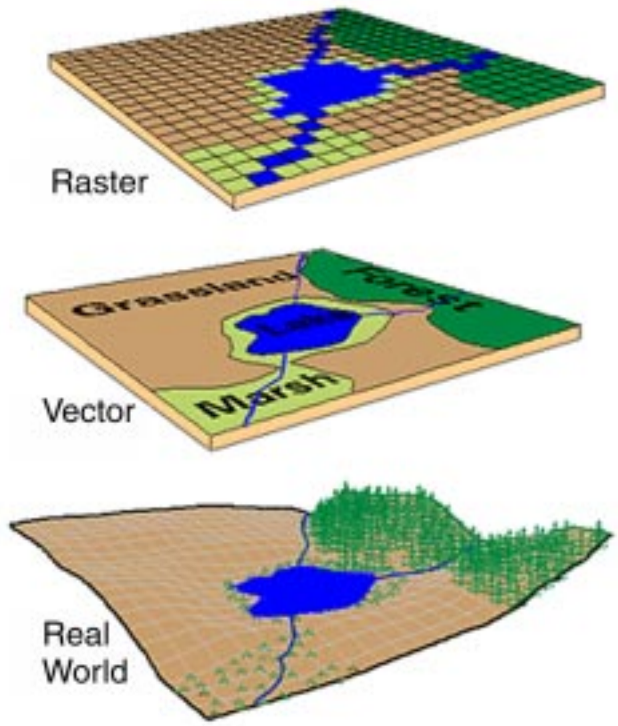

Figure 6-1. GIS Data Layers May Use Raster or Vector Representation Techniques.

such as a latitude and longitude or national grid coordinate, or an implicit reference such as an address, postal code, census tract name, or road name. An automated process called geocoding is used to create explicit geographic references from implicit references (descriptions such as addresses). These geographic references allow you to locate features, such as a Superfund site, and events, such as the location of a major chemical spill, on the earth's surface for analysis. In the vector model, information about points, lines, and polygons is encoded and stored as a collection of *x,y* coordinates. The location of a point feature, such as a point source discharge, can be described by a single *x,y* coordinate. Linear features, such as roads and rivers, can be stored as a collection of point coordinates. Polygonal features, such as watershed catchments or the boundaries of political units such as towns, can be stored as a closed loop of coordinates.

The geocoding process can be the most time-consuming and resource-intensive step in a GIS analysis and mapping process. Data layers involving point or polygon features can be especially difficult to digitize to high degrees of precision. On the other hand, point coverages are often much easier to create. For point coverage, the main requirements are an accurate set of latitude and longitude coordinates or locational information from Global Positioning Satellite (GPS) tools. Point data layers (or coverages) can also be created using existing line or polygon

Table 6-1. Comparison of Raster- Versus Vector-Based GIS Programs

	Raster Method	Vector Method
Advantages	• Simple data structure • Overlay and combination of mapped data with remotely sensed data is easy • Various kinds of spatial analyses are easy • Simulation is easy because each spatial unit has the same size and shape • Technology is inexpensive and is being actively developed	• Good representation of phenomena (such as county and towns, or soil structure hierarchies) • Compact data structure • Topology can be described completely with network linkages • Retrieval, updating, and generalization of graphics and attributes are possible
Disadvantages	• Volumes of graphic data • Use of large cells to reduce data can lose important data, so frequently cannot simplify information • Raster map graphics are more crude than vector maps drawn with fine lines • Network linkages are difficult to establish • Projection transformations are time consuming unless special algorithms or hardware is used	• Complex data structures • Combination of several vector maps through overlay creates difficulties • Simulation is difficult because each unit has a different topological form • Display can be expensive, particularly for high quality, color, and cross-hatching • Technology is expensive, especially for more sophisticated software and hardware • Spatial analyses and filtering within areas are impossible
Recommended Uses	• Quick and inexpensive overlay, map combination and spatial analyses • Simulation and modeling when working with surfaces is necessary	• Data-archiving phenomena (e.g., soil areas, land-use units) • Network analyses (e.g., telephone networks or transportation networks) • Compact digital terrain models

Source: Burrough (1991).

coverages as base maps, from which the point locations can be supplied using software tools in a GIS.

A sensible strategy in conducting special risk analysis or risk management projects with GIS is to identify what data layers are already available and keep the coverages that must be created from scratch to a minimum. The new coverages, in many cases point coverages, would be based on site-specific information based on special surveys or data collections. For existing coverages or georeferenced data files, facilities accessible through the Internet and the World Wide Web (WWW or WEB) are making it easier to locate and obtain, often for free), a variety of useful data products. Major impetus for using the Internet to exchange GIS data has come from the Federal initiative known as the National Spatial Data Infrastructure. EPA has strongly supported this effort and, in partnership with other Federal and State agencies, now offers a broad spectrum of valuable data products through its Web pages.

6.4 INTERNET SOURCES OF EXISTING DATA FILES AND GIS COVERAGES

A consortium of major governmental agencies cooperates through the Federal Geographic Data Committee (FGDC) to encourage the widest possible use of good quality spatial data products. The main mechanism for sharing these information products is through a series of special Internet facilities maintained by individual Federal or State agencies, university research groups, and private firms called the National Spatial Data Infrastructure (NSDI). The NSDI is conceived to be an umbrella of policies, standards, and procedures under which organizations and technologies interact to foster more efficient use, management, and production of geospatial data. The Clinton Administration has tasked the FGDC to provide the Federal leadership for evolving the NSDI in cooperation with State and local governments and the private sector.

The Internet provides a number of interactive software tools to share information, but the most popular tools center on the use of Web browsers that are available for computers of all types ranging from sophisticated workstations to personal computers. A growing number of private citizens use Web browsers at their homes by subscribing with companies known as Internet Service Providers. Internet access is also available through colleges, libraries, research institutes, and government agencies. Web sites are identified by special addresses called Universal Resource Locators (URLs). The URL providing general information for the entire National Spatial Data Infrastructure is:

http://fgdc.er.usgs.gov/

This central hub for the NSDI provides Web links to a number of other major “nodes” in the NSDI system. Federal agencies such as the Census Bureau, the United States Geological Survey (USGS), the United States Department of Agriculture (USDA), and EPA have their own NSDI WEB pages with links to more specialized data items. EPA’s link to the NSDI is at

http://nsdi.epa.gov/nsdi/

EPA has also established a number of Web pages to help provide background information or help access actual data products dealing with particular databases or agency programs. Examples include a facility called SURF YOUR WATERSHED that acts as a gateway to information organized according to standard watershed catchments called Hydrologic Cataloging Units defined by the USGS, and an Internet data warehouse system called ENVIROFACTS that allows the retrieval of information dealing with permitted facilities (e.g., Permit Compliance

Systems (PCS) for point source discharges to receiving waters), Superfund (or Comprehensive Environmental Response, Compensation, and Liability Act List of Sites [CERCLIS]), and information from databases such as the Toxics Release Inventory (TRI).

With the EPA Web facilities, data files or GIS coverages may be downloaded that could then be incorporated into risk assessment and management projects; the end user would then need access to a GIS to perform spatial analyses and produce the final GIS maps. EPA is also setting up Web facilities at which the user can provide inputs on the type of analysis to perform and then retrieve maps directly from the Internet link. An example is given in Figure 6-2 of a new Web tool called BASINInfo that can produce displays of the major types of permitted facilities within a USGS Cataloging Unit.

EPA’s SURF YOUR WATERSHED facility provides an on-line set of maps derived from the Office of Science and Technology’s North American Fish and Wildlife Consumption Database (NAFWCD). Figure 6-3 shows a display depicting the locations of active advisories for the State of North Carolina. GIS maps showing the location of fish advisories in any of the 50 States, U.S. Territories, and the District of Colombia can be viewed on this system.

6.5 DATA NEEDED FOR MAPPING

The information needed for a given map depends largely on the objective of the map itself. The following major categories of information are useful for mapping:

- Chemical contaminant type and concentration
- Consumer population
- Risk level.

Additional refinements may be desirable, including the relationship of chemical contaminants to various point or nonpoint sources, demographic characteristics of the consumer population, consumption patterns of population groups, and types and levels of human health risks. At a minimum, contaminant mapping is usually possible because sampling and analysis programs are basic to all fish advisory programs and generate the necessary data to map the locations where various contaminants are detected as well as the fish species and size (age class) in which the contaminant occurs. Individual maps for each contaminant may be generated, or maps of several contaminants can be displayed together if there is sufficient refinement in the system. Contaminant concentration can be indicated using different colors; through graphic patterning such as cross-hatching, lines, and dots; or through the use of different symbols (open, semiclosed, or closed circles or squares).

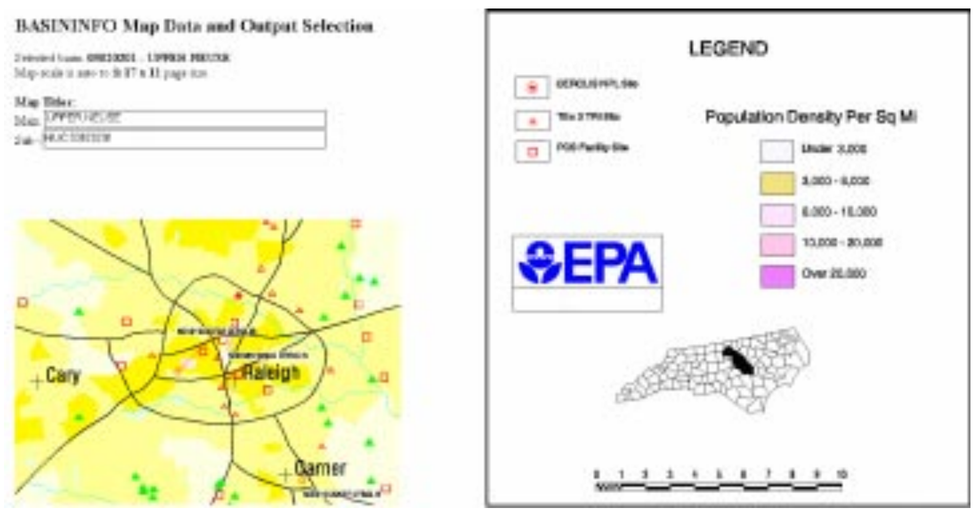

Figure 6-2. Examples of GIS Displays from EPA's BASINInfo Maps-on-Demand Facility.

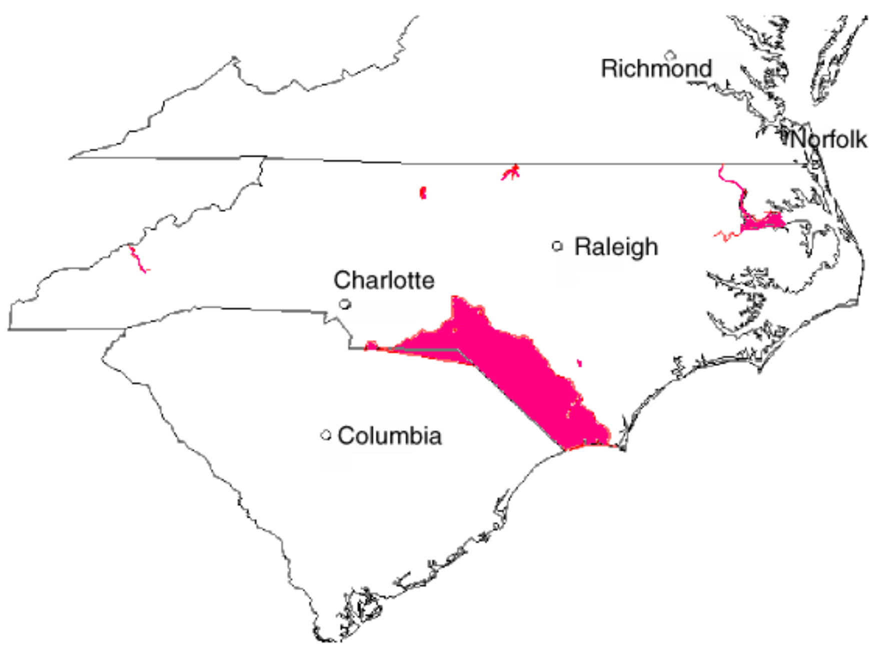

Figure 6-3. Map Showing Active Fish and Wildlife Advisories for a State.

6.6 MAPPING PROGRAMS

Computerized mapping programs are useful aids; however, mapping programs take some time to learn and require data collection and organization prior to data entry. State and local agencies interested in digital mapping should consider the following:

- Availability of the data needed for each map
- Quality of the data to be used
- Amount of time and money available
- Type of program used to generate maps
- Purpose of each map or map series for developing consumption advisories.

It is important to evaluate the goals of the mapping effort and the resources available for the activity. Using a program that does more than is needed can result in unnecessary expenditures for staff training and developing maps for analysis. Data storage capacity is also an important consideration and may be a factor in choosing a mapping approach.

Many Federal, Regional, State, and Tribal agencies already have some divisions that are using GIS programs for other purposes. It is cost- and time-effective to consult with staff already using this resource. Several mapping programs are available that are relatively uncomplicated and inexpensive. These programs are often called desktop mapping or desktop GIS packages. One example of a commercial desktop GIS package is ESRI's ArcView, which can be set up on a personal computer. Generally, PC-based programs can be used to digitize field map data onto a computer, but these programs often have limited capacity to accommodate large data sets. Although more sophisticated programs that usually require high-performance workstations as their computer platforms offer greater flexibility in data input and manipulation, they are often an expensive option and require more expertise to set up and operate. Most GIS programs can generate large volumes of data that need to be stored, so consider computer space in advance.

One cost-effective and sophisticated program, run as a nonprofit venture, has been used extensively by international nongovernmental organizations (NGOs) and intergovernmental organizations with great success. IDRISI (whose name is taken from a medieval Arabic geographer who lived in what is now Morocco) is available from the Geography Department of Clark University in Massachusetts. It consists of inexpensive software that can use and manipulate data easily and also be programmed to assist in selecting outlining criteria for management analyses. The program cost was $650 (government rate) in 1995. The University offers training workshops and other assistance for new users (including Applications in Forestry, Coastal Zone Research and Management, and Decision Making), which may be useful for fish advisory program staff. The IDRISI program is a raster-based system, so the analyses conducted by the program are performed rapidly, effectively, and relatively inexpensively. This particular program is sophisticated enough to accommodate some of the more complicated analyses that are normally difficult to perform without a vector-based program.

Mapping information for the development and management of fish advisories is a relatively new undertaking for most agencies. EPA welcomes ideas and recommendations on this topic. Examples of maps or mapping methods provided to EPA, which are widely applicable, are especially welcome.